On Performance Improvement Techniques and Geospatial Data Visualisation of Large Scale Agent-Based Models: A Case Study on Computational Simulation of an Old World Screwworm Fly Invasion of Australia

By

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A thesis submitted in fulfilment of the

Doctor of Philosophy (PhD)

University of New England,

Australia

February, 2014

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification. I certify that any help in preparing this thesis, and all sources used, have been acknowledged in this thesis.



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Signature

Acknowledgements

I would like to acknowledge the contributions of Animal Health Australia (AHA) for providing the top-up PhD scholarship for this project, Dr David Mayer (Department of Primary Industries, Queensland Government) for his advice and expertise regarding existing modelling systems, Dr Sam Beckett (SDB bio) for his guidance regarding the biological components of this work and Dr David Miron for introducing me to this project.

I would like to thank my supervisors Associate Professor Paul Kwan and Professor A.S.M. Sajeev for their management and direction of this project. Without their supervision and constant help this thesis would not have been possible.

Finally I would like to thank my wife for her invaluable support over the course of my studies. Without her support I would not have been able to devote the time and effort that has gone into this thesis.

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Abstract

The Old World Screwworm Fly (OWSWF), *Chrysomya bezziana*, is an insect pest that is endemic to the tropical regions of Asia, the Middle East and Africa, that reproduces by laying its eggs in open wounds and mucus membranes on warm blooded mammals. Upon hatching, the OWSWF larvae eat the living flesh of the host animal, causing injury, secondary infections and in extreme cases death. If this pest was introduced to the Australian mainland, it could have a devastating impact on the livestock industries within the northern regions of Australia. In order to plan and respond to the threat of the introduction of this pest into the Australian mainland, government authorities require a modelling capability to support both decision making and policy creation. This thesis builds upon the existing research surrounding the OWSWF biological lifecycle and dispersal characteristics to develop a national-scale, high-resolution, agent-based model that simulates an invasion of Australia by the OWSWF.

The scale and level of details presented within this model represent a highly computationally complex and intensive system with significant processing overhead. In order to develop an implementation of the model capable of supporting the computational load, this thesis explores the use of data compression and aggregation techniques to improve the efficiency of agent-based modelling systems. A case study implementation of a hierarchical data compression scheme showed promising results; however, a detailed post-analysis revealed that the approach developed would not be suitable for the proposed agent-based OWSWF model. Ultimately, the study makes use of *Graphics Processing Unit* technologies, based around NVidia's *Compute Unified Device Architecture* (*CUDA*), to simulate the lifecycle and dispersal of the OWSWF at both the individual insect and cohort levels. The resultant model combines agent-based logic, for simulating the OWSWF's lifecycle, with an efficient cellular-automata system to capture the spatial aspects of the OWSWF population's dispersal over the course of the simulated invasion. The implementation scheme adopted breaks the agent's logic down into CUDA *kernels* and uses a heterogeneous programming approach to distribute processing tasks between the CPU of the host machine and the CUDA device to achieve an efficient execution on the available technology.

This thesis goes on to examine the integration of advanced Geographical Information Systems (GIS) with agent-based modelling systems for analysing spatial output. This study makes use of customisations within off-the-shelf GIS software to produce an implementation that allows GIS software to directly access and present model output. This implementation scheme allows for complex spatial queries between simulation results and external spatial data layers, providing a platform to support the activities of policy makers. The capabilities of this integration scheme are demonstrated in a detailed sensitivity analysis that demonstrates the impacts of varying the contributing factors or parameters on the OWSWF's population distribution.

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